

INTELLIGENT ROBOTIC TRACKER

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An intelligent tracker capable of robotic applications requiring guidance and control of platforms, robotic arms, and end effectors has been developed. This packaged system capable of "supervised autonomous" robotic functions is partitioned into a multiple processor/parallel processing configuration. The system currently interfaces to cameras but has the capability to also use three dimensional inputs from scanning laser rangefinders. The inputs are fed into an image processing and tracking section where the camera inputs are conditioned for the multiple tracker algorithms. An executive section monitors the image processing and tracker outputs and performs all the control and decision processes. The present architecture of the system will be presented with discussion on its evolutionary growth for space applications. An autonomous rendezvous demonstration of this system was performed last year at JSC. More realistic functional demonstrations using the MMU simulator and the manipulator development facility planned for this year will be discussed.

INTRODUCTION

The purpose of this project was to functionally demonstrate the McDonnell Douglas Astronautics Company (MDAC) Robotic Tracking Sensor in autonomous homing and contour following modes. The major benefit of this demonstration was the application of existing technology to space operations in order to evaluate the ability of this equipment to meet near term autonomous tracking and sensing requirements with low hardware and software development costs. The scope of this project was purely a functional demonstration resulting in qualitative data. A more structured, quantitative test can be performed at the completion of the upgrade of the Laser Optical Tracking Testbed facilities in Building 14 at JSC. This demonstration addressed only the homing and contour following modes. More realistic space operations such as inspection, maintenance, assembly, and retrieval would be addressed later.

MDAC Tracking Sensor

The architecture of the multimode sensor tracker is shown in Figure 1. The multiprocessor tracker is composed of three functional parts:

- 1) Two Fairchild CCD 3000 cameras and video processor.
 - 2) The MDAC 673 image and tracker processor.
 - 3) The Z8000 executive control processor.
- The video tracking functions are computation intensive requiring a high throughput special purpose signal processor. To match the video data with the bandwidth of the image processor, data compression is performed by the video preprocessor by either excluding regions of the scene that are of no interest or by performing a pixel averaging. This effectively performs video windowing and an electronic zoom. The preprocessor also performs a tracker controlled brightness and contrast adjustment to the video image. This enhances the tracker's capability to see and track the target.

The MDAC 673 is a high speed, 10 MOPS, special purpose microcodable signal processor. All tracking functions are performed in the MDAC 673. Existing algorithms are: (1) correlation, (2) centroid, (3) conformal gate, and (4) guard gate. The primary trackers required for these demonstrations were the correlation and centroid trackers. The correlation tracker is a feature tracker that tracks by finding the best match of a video reference image with the scene. The centroid tracker is a contrast tracker that finds the center of the target exhibiting intensities above or below a controllable threshold. The conformal gate and guard gate trackers were required for countermeasure techniques or when the target background exhibited a lot of clutter. The conformal gate tracker is a statistical tracker that classified the scene as either background, target, or unknown. This tracker finds the target boundary and maintains the tracker gate size to enclose all of the target. The guard gate tracker detects when the target passes behind obstacles and controls the other tracker's operations while the target is not visible.

The Z8000 executive control processor directs the operation of the multimode trackers, provides operator interface, and controls the responses of either vehicles or mechanisms. The executive processor controls acquisition of the target, monitors each tracker's aimpoint, and can reinitialize any tracker algorithm during the engagement. The operator interface is provided through the hand controller and the video monitor mounted on the tracking sensor. The tracking sensor was mounted on a mobile platform manufactured by Cybermation.

System Configuration

The MDAC tracking sensor was integrated with the Cybermation platform through a serial link between the MDAC Z8000 processor and Cybermation processor. The tracking sensor computer and electronics were mounted on the Cybermation turret mount. The long range camera was oriented with the platform wheels. Figure 2 shows a block diagram of the interfaces. The executive control software was modified for autonomous tracking and control of the decision logic. Specifically, two modes are engaged by the executive control software: homing and contour following. While in the homing mode, the tracking sensor monitors the target position while guiding the platform to a specified distance from the target as determined by the camera image size. The executive then switches to the contour following mode. This mode commands the platforms to move laterally around the target by using a structural feature of the target. The tracking sensor remains at the specified range with the target in the center of view. At the completion of one revolution, the platform is stopped. A third mode was added to the executive control software in order to accentuate the autonomous features of the tracking sensor. In this mode, the "heel" mode, the tracking sensor tracks and follows a target while maintaining a specified distance from the target as determined by camera image size. When the platform gets within this specified range, it stops with the tracker still maintaining lock-on of the target even if the target moves around the platform within the specified range. When the target moves away from the platform, the tracking sensor again commands the platform to follow the target.

Functional Demonstrations

The tracking sensor was demonstrated in the Laser Optical Tracking Testbed in Building 14 at JSC during the week of 21 July 1986. Figure 3 shows the demonstration format. The demonstration began with a manual acquisition of the target at a range of up to 100 feet. The tracking sensor locked on to the target in the acquisition gate and guided the platform to the target at a fixed rate while keeping

the target in the center of the field of view. At a range of approximately ten feet from the target, the tracking sensor switched from the long range camera to the short range camera. At a range of approximately four feet, the platform was halted and the tracking sensor switched from the homing mode to the contour following mode. Here the tracking sensor tracked a structural feature on the target to guide the platform around the target. During this maneuver, the long range camera remained in a forward orientation while the short range camera was rotated on the rotary table to maintain tracking of the target. After completely circling the target, the platform was halted and the cameras realigned. At this point, the tracking sensor and platform were ready for further commands from the operator. The "heel" mode was also demonstrated to illustrate the autonomy of the tracking sensor. After a manual lock-on of the target, the demonstration proceeded to lead the tracking sensor and platform around the testbed. Various starts, stops, turns, pivots, and obstacle avoidance maneuvers were demonstrated.

Tracker Upgrades

The tracker configuration used in these demonstrations was developed in 1981. Upgrades to increase its computing capability, reduce its size, and lower its power consumption are being implemented. CMOS devices will be used allowing the processor speed to be increased from 5 to 10 MIPS for the array processor and from 300 KIPS to 1 MIPS for the executive processor. A floating point chip will be added. The pixel rate will be increased from 5 to 15 MHz. Several boards (video preprocessor and interface) will be reduced to a single 300 X 300 mil chip. Overall, the power consumption of the packaged tracker will be reduced from 200 to 25 W and the number of cards from 11 to 5. It is anticipated that a version of this packaged tracker could be used in the Orbiter cabin.

Advanced Robotic Demonstrations

In coordination with NASA-JSC, the MDAC tracker will be interfaced with two of NASA's operational systems: 1) Man Maneuvering Unit (MMU), 2) One-G version of RMS. When interfaced to the MMU, the tracker will provide both target identification and guidance cues to the control systems for autonomous operations. Likewise, when interfaced to the 1-G RMS arm, the tracker will guide the end effector to targets which were manually acquired by an operator. Cameras mounted on the MMU and 1-G RMS will provide the necessary imagery for the tracker.

CONCLUSION

The capability of existing, packaged tracker hardware to perform autonomous homing and contour following with minor upgrades were functionally demonstrated. Upgrades in hardware and software will be required to address the requirements of space operations. However, a great deal of the basic development have already been and are being performed and funded by other government agencies. The demonstrations with the MMU and 1-G RMS arm will provide additional information on the integration of this technology with existing systems for near term space operations.

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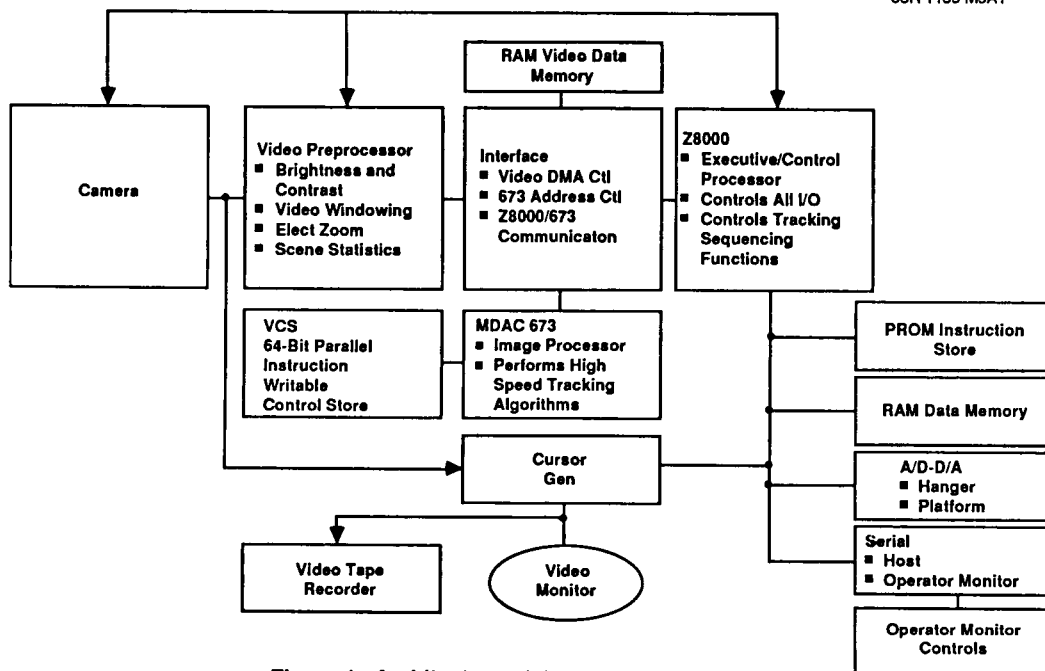


Figure 1. Architecture of the MultimodeTracker

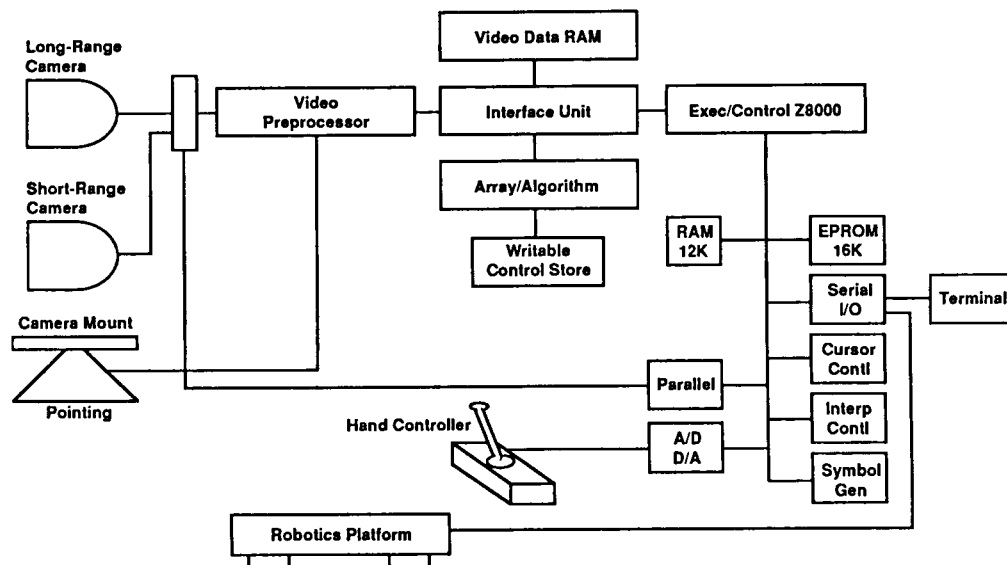


Figure 2. MDAC Tracking Sensor/Mobile Platform Integration Diagram

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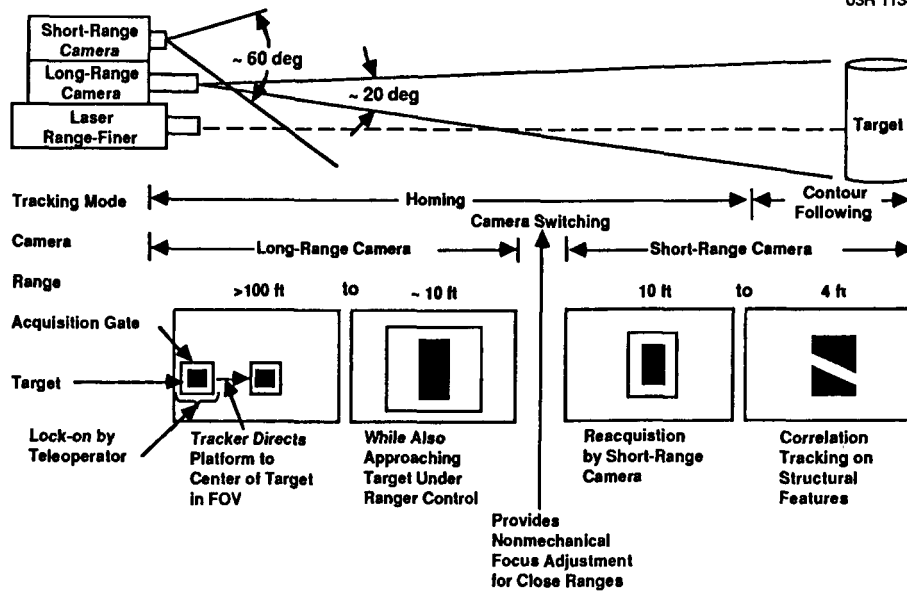


Figure 3. Demonstration Format